



# A Product Development Team for Snow and Ice Climate Data Records

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CDR Team Meeting  
July 31 – Aug 2, 2012

# Project Description: Personnel

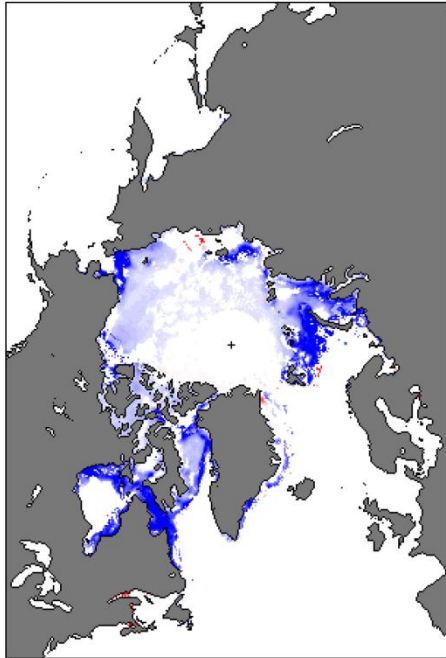
- **Jeff Key** (PI), NOAA/NESDIS
- **Xuanji Wang**, University of Wisconsin
- **Yinghui Liu**, University of Wisconsin
- **James Maslanik**, University of Colorado
- **Walt Meier**, University of Colorado
- **Mark Tschudi**, University of Colorado
- **Charles Fowler** (ret.), University of Colorado
- **Julienne Stroeve**, University of Colorado
- **William Emery**, University of Colorado
- **Dorothy Hall**, NASA/GSFC

# Use-Inspired Science from Cryosphere CDRs

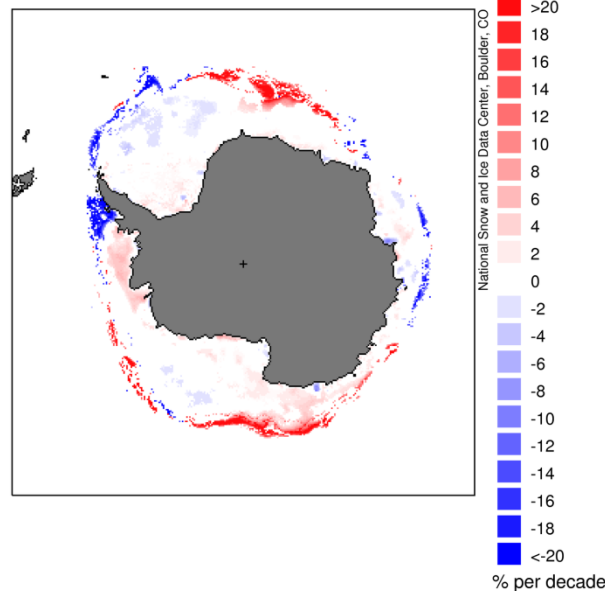
Sea Ice Index, [http://nsidc.org/data/seaice\\_index/](http://nsidc.org/data/seaice_index/)

- Imagery, timeseries, anomalies trends
- Plan to transition to use CDR concentration as input

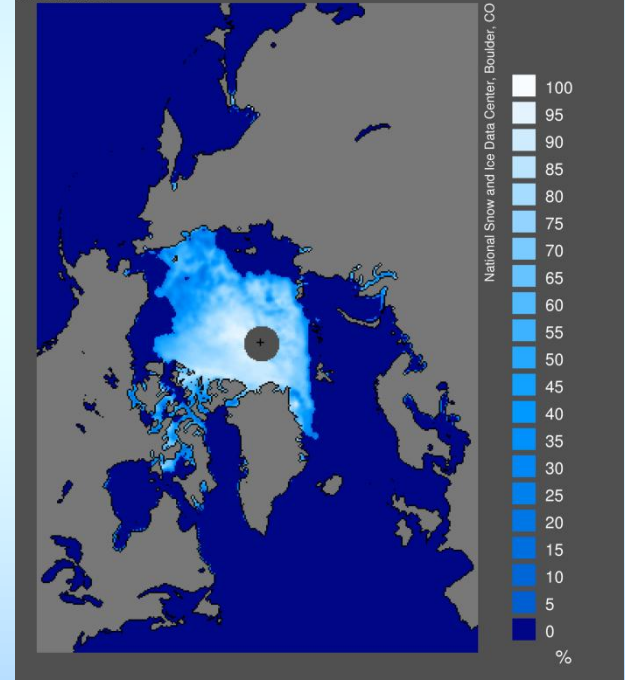
Sea Ice Concentration Trends  
Jun 2012



Sea Ice Concentration Trends  
Jun 2012



Sea Ice Conc  
07/30/2012



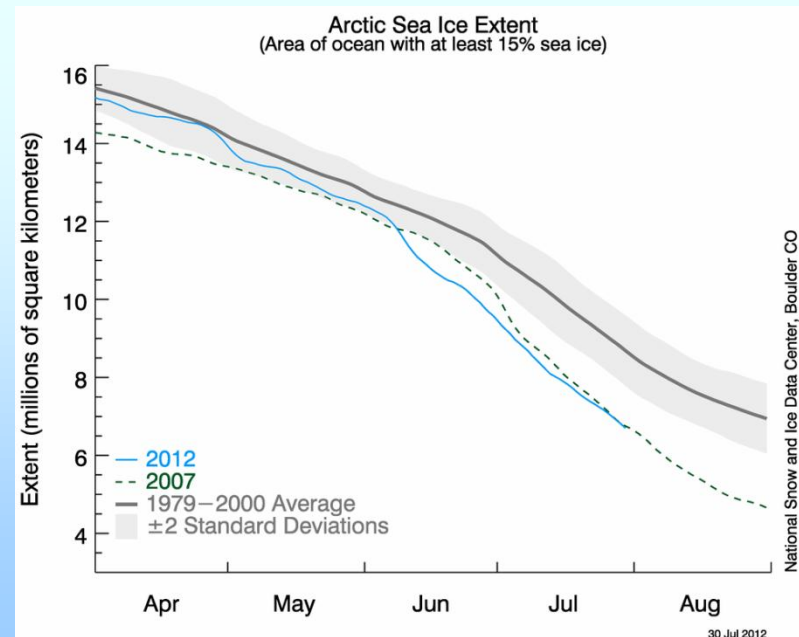
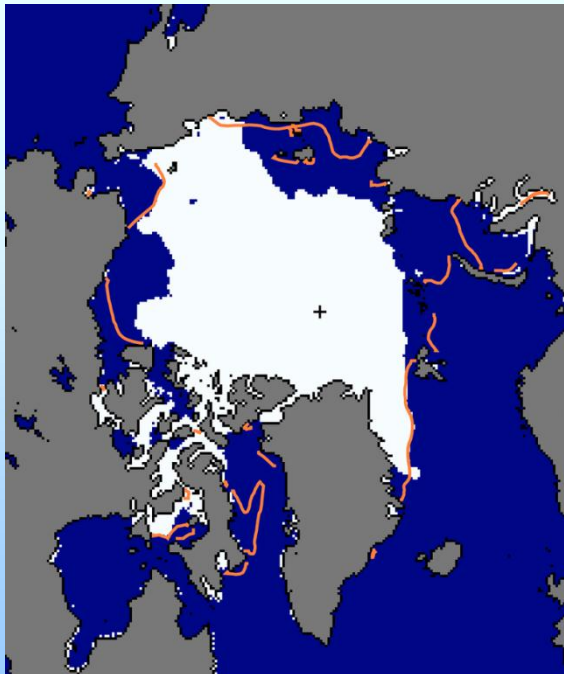
NOAA@NSIDC, F. Fetterer, program manager  
(includes many other cryospheric data products)

# Use-Inspired Science from Cryosphere CDRs

## Arctic Sea Ice News and Analysis

- <http://nsidc.org/arcticseaicenews/>
- Funded by NASA Cryosphere Program
- Uses Sea Ice Index as basis for imagery and analyses
- NSIDC's most visited website
- Used by scientists, strategic defense planning, commercial interests (oil drilling), policymakers, educators, media

30 July 2012



# Use-Inspired Science from Cryosphere CDRs

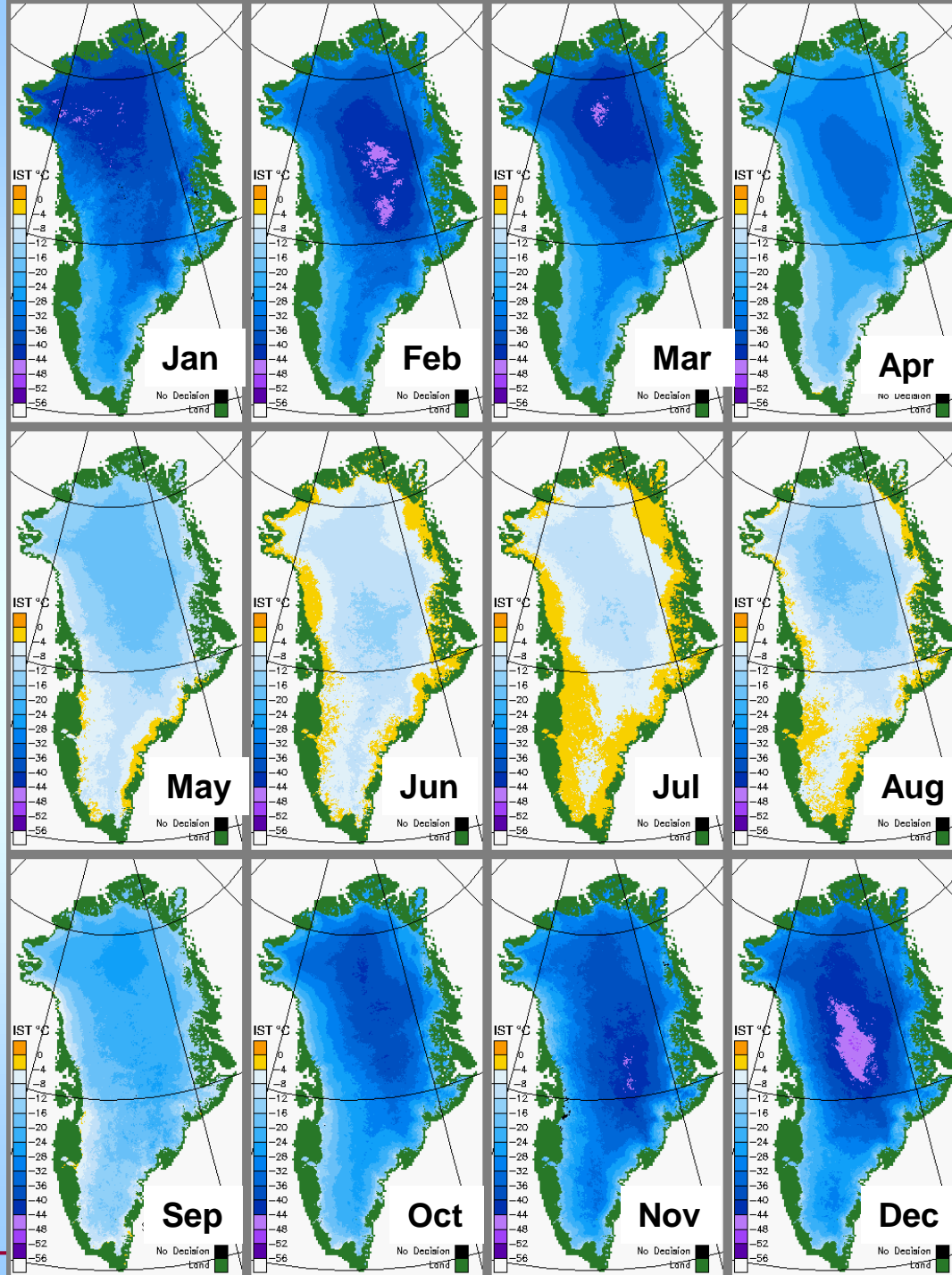
## Lagrangian Tracking of Arctic Sea Ice Age



NOAA Climate Watch

<http://www.climatewatch.noaa.gov/video/2011/old-ice-becoming-rare-in-arctic>

# Monthly-mean MODIS ice-surface temperature (IST) color-coded maps for 2010



Dataset available at:  
<http://modis-snow-ice.gsfc.nasa.gov>

Hall, D.K., J.C. Comiso, N.E. DiGirolamo, C.A. Shuman, J.R. Key and L.S. Koenig, 2012: "A Satellite-Derived Climate-Quality Data Record of the Clear-Sky Surface Temperature of the Greenland Ice Sheet," *Journal of Climate*.

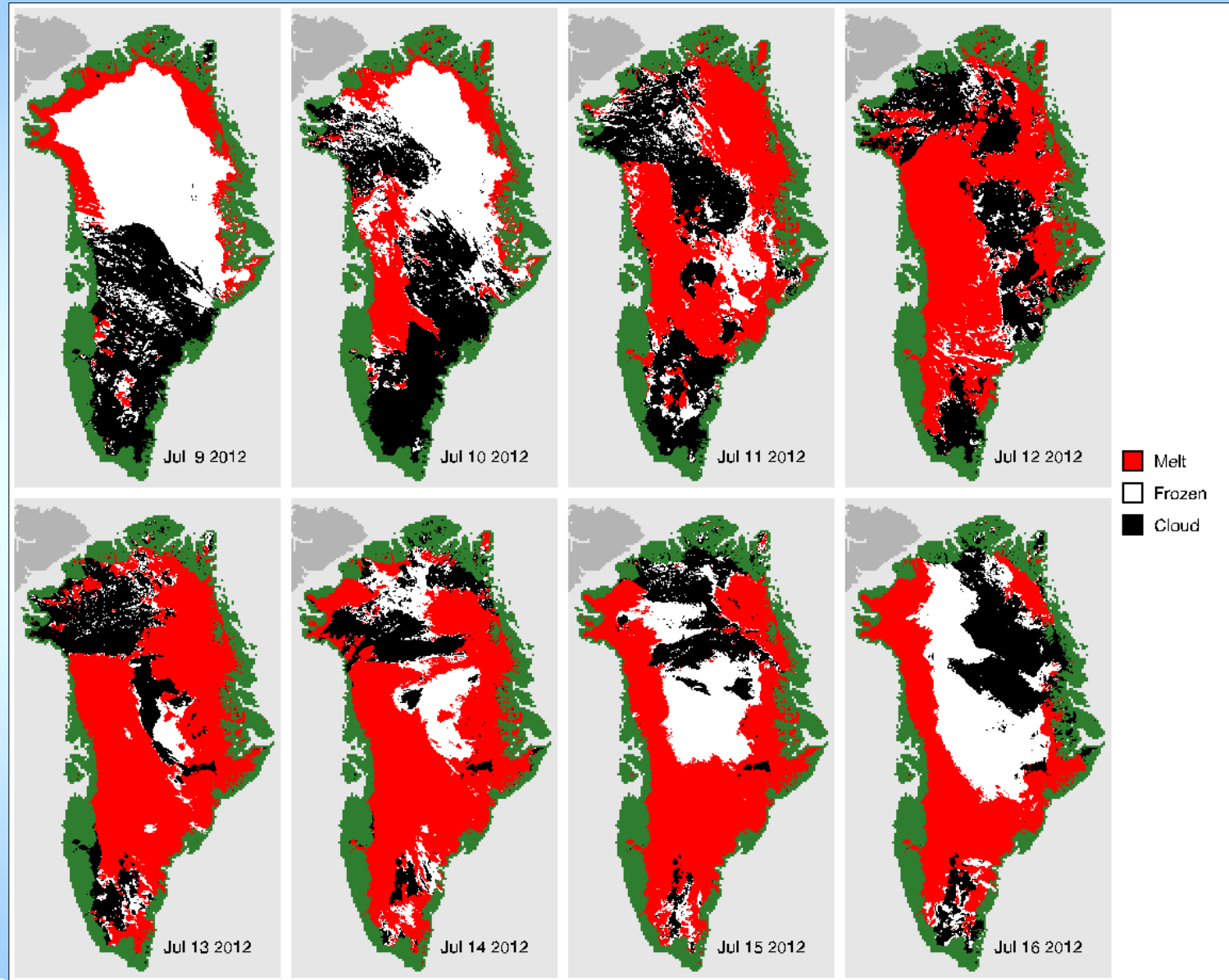
# MODIS Ice-Surface Temperature (IST) Climate-Quality Data Record

- Developed using MODIS Terra and Aqua data
  - Daily and monthly maps
    - downloadable online at: <http://modis-snow-ice.gsfc.nasa.gov/>
  - 6.25-km spatial resolution
  - Uncertainty information in each grid cell
  - Suitable for continuation using the Visible/Infrared Imager Radiometer Suite (VIIRS) to create a CDR
- Studied 12-year trends in surface temperature and melt extent



# MODIS-Derived Melt Maps of the Greenland Ice Sheet\*

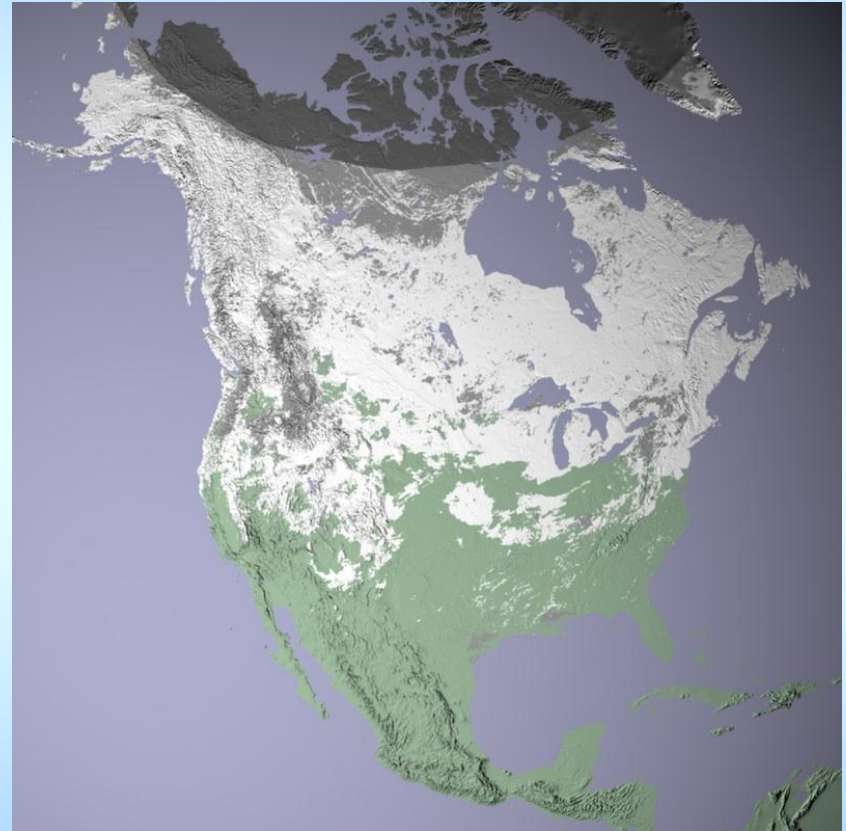
showing major mid-July 2012 melt





# Northern Hemisphere Snow Extent Earth System Data Records

- Assess compliance of current NH snow cover products over land, sea ice and the Greenland ice sheet with NRC Climate Data Record (Earth System Data Record) characteristics
- Blend data records using statistical measures to develop enhanced, ESDRs of NH snow conditions
- Make the ESDRs and associated products available to the user community via an existing web site (<http://climate.rutgers.edu/snowcover/>) and encourage their use.
- Use MODIS snow products for validation of enhanced ESDR, and for snow mapping since 2000



# Project Description: Overview

The cryosphere product development team is *coordinating the generation, validation, and archival of fundamental and thematic snow and ice climate data records.*

Our goal is to refine, extend, validate, document, and archive visible, infrared, and passive microwave cryosphere products. *We are building on existing efforts, coordinating with other funded products, as appropriate.*

Products include sea ice concentration, extent, thickness, and age; snow cover; snow/ice surface temperature and albedo; polar cloud properties; surface shortwave and longwave radiation.

# Project Description: Products

CDR(s) (Validated Outputs)	Period of Record	Spatial Resolution; Projection information	Time Step	Data format	Inputs	Uncertainty Estimates (in percent or error)	Collateral Products (unofficial and/or unvalidated)
AVHRR Polar Pathfinder extended (APP-x)	1982 - 2011	25 km, EASE- Grid, Arctic and Antarctic	Twice- daily local solar time	netCDF4	AVHRR level-1b, NCEP GFS model fields	Various (many products), 5- 20%	
Sea Ice Motion	1979-2011	25 km, EASE grid	Daily	Text, binary	AVHRR, SSM/I, AMSR, IABP buoys, NCEP surface winds	5 cm/sec	
Sea ice Age	1982-2011	25 km, EASE grid	Weekly	binary	Sea Ice Motion	1 year of age	
PM sea ice conc.	1987-2007 (1978-2011)	25 km, polar- stereo, Arctic, Ant.	Daily, Monthly	netCDF4	SMMR, SSM/I, SSMIS	5-10% (higher in some regimes)	Melt onset as part of quality info

# Project Description: Products, cont.

CDR(s) (Validated Outputs)	Period of Record	Spatial Resolution; Projection information	Time Step	Data format	Inputs	Uncertainty Estimates (in percent or error)	Collateral Products (unofficial and/or unvalidated)
AVHRR Polar Pathfinder (APP)	1982 - 2011	5 km, EASE- Grid, Arctic and Antarctic	Twice-daily local solar time, 0400 and 1400 Arctic, 0200 and 1400 Antarctic	binary	AVHRR level-1b	5-10%	
AVHRR Sea Ice Concentrati on	1982-2011	25 km Ease Grid, Arctic and Antarctic	Twice-daily Solar Local Time, 0400 and 1400 Arctic, 0200 and 1400 Antarctic	binary	AVHRR level-1b, retrieved ice surface temperatur e		unofficial
Greenland IST	2000-2011	6.25-km polar stereograph ic grid	Daily		MODIS	3 K	

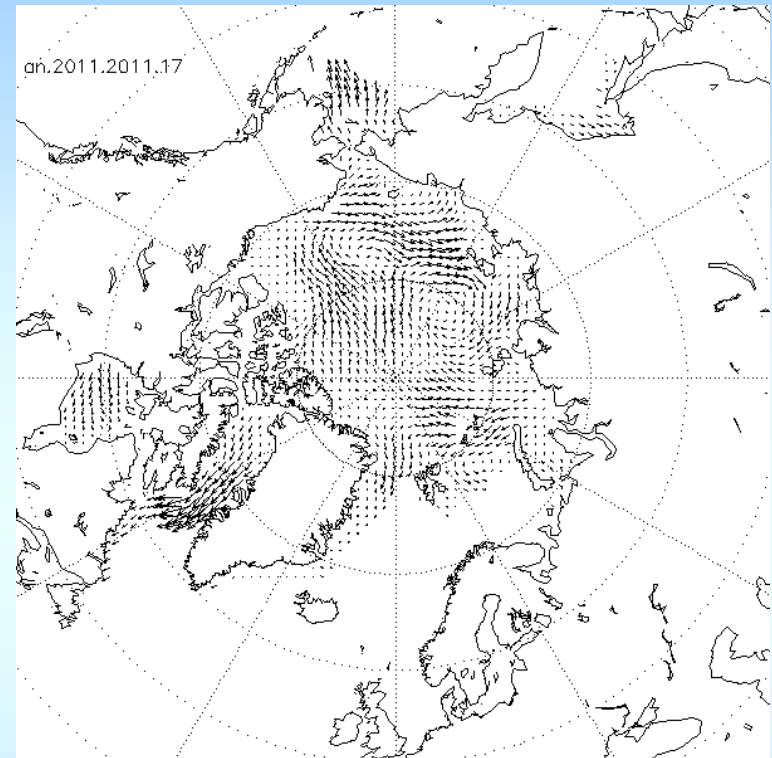
# Ice Motion

## Algorithm:

- Daily sea Ice motion based on correlating successive daily passive microwave images.
- Correlation also performed simultaneously with IABP ice buoy trajectories and NCEP surface winds.

## Validation:

- Product has been validated vs. various data sets by multiple investigators. These efforts will continue.
- The effects of loss of tracking during parts of the summer (due to surface melt) on ice motion errors is being evaluated.



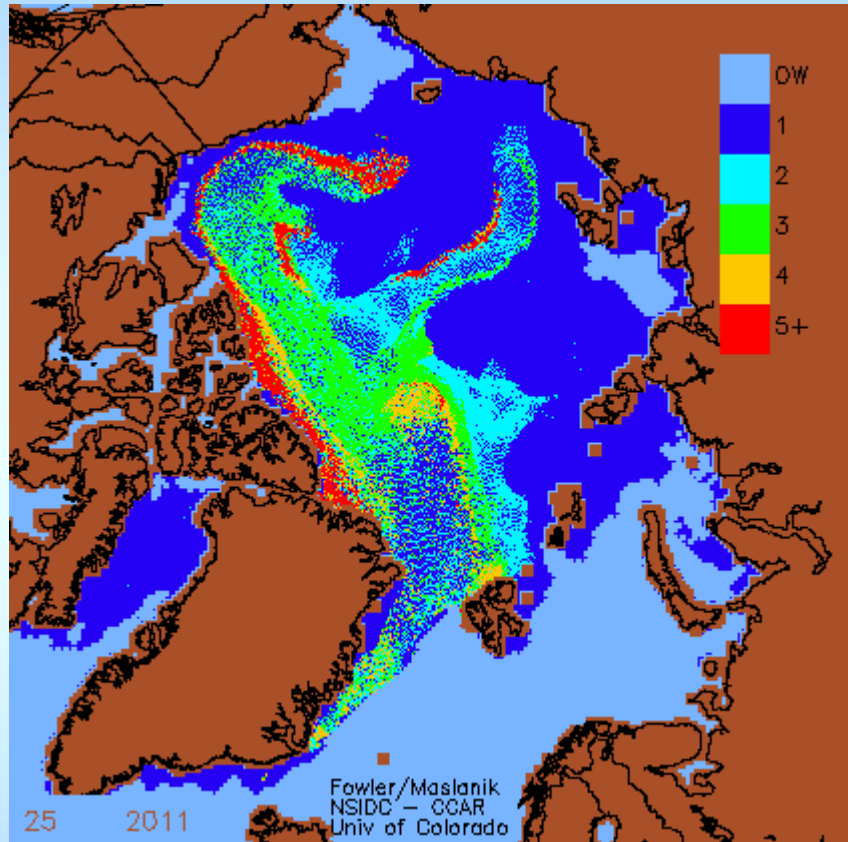
# Ice Age

## Algorithm:

- Lagrangian tracking of ice to determine age, in years
- Utilizes ice motion vectors

## Validation:

- Compare spatial patterns of ice age to aircraft data from multiple existing efforts [e.g. NASA IceBridge flights (imagery and LIDAR profiling)]
- Examine temporal and spatial consistency compared to complementary satellite data (ICESat, QuikSCAT, ENVISAT)





# Passive Microwave Sea Ice Concentration

## Algorithm:

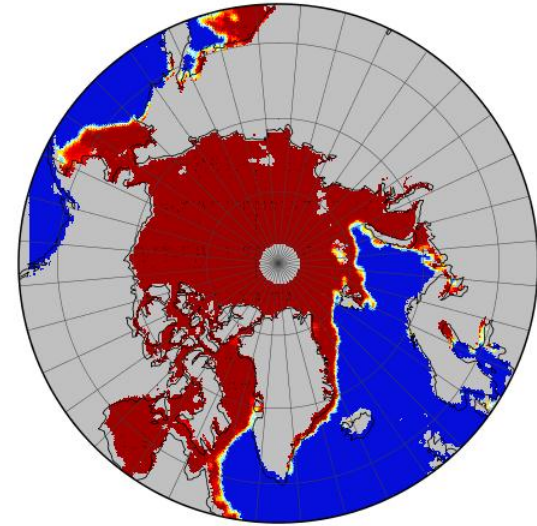
- Combined NASA Team and Bootstrap
- Bootstrap ice edge
- Selects higher concentration value
- Spatial standard deviation field of both of algorithm estimates as data quality indicator

## Validation:

- Both algorithms have had numerous validation studies conducted, comparisons with in situ, airborne, and higher resolution satellite data
- CDR concentration estimates compared with individual algorithm products

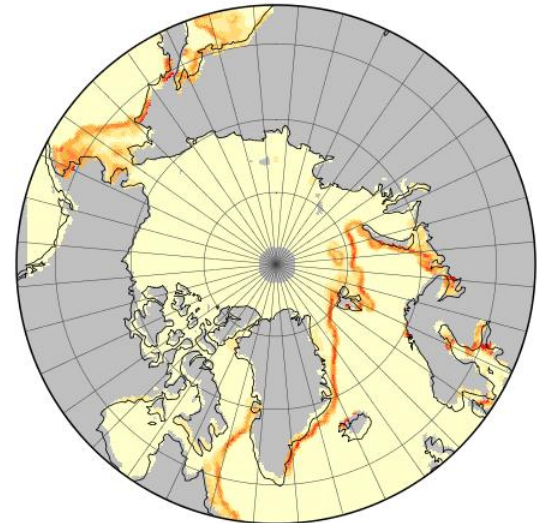
Concentration

15 March 2007



Standard Deviation

15 March 2007



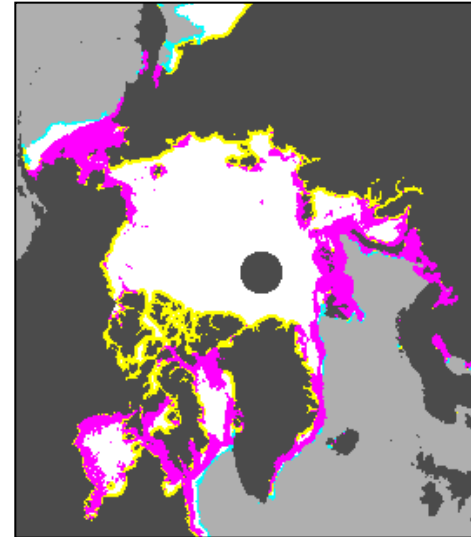
# Melt Onset

## Drobot-Anderson Algorithm:

- Passive microwave temperature difference between 19 and 37 GHz channels
- SSM/I, SSMIS

*Melt onset is included as part of the PM sea ice concentration product in the quality assessment field. Arctic only.*

15 March 2007



Melt  
< 50%  
Coast

Quality Assessment

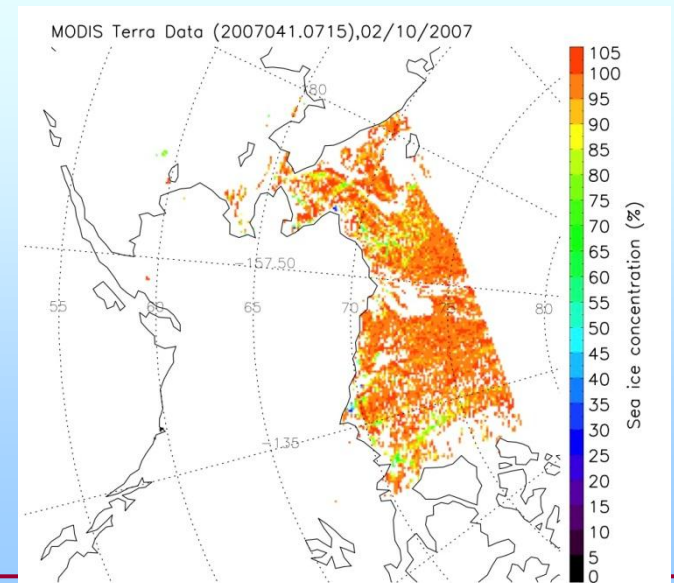
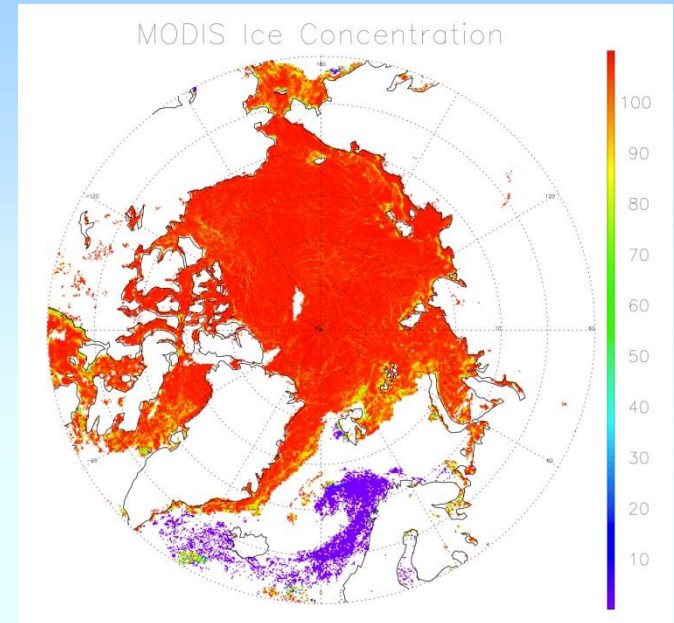
# Ice Concentration and Ice Mask from vis/IR

## Algorithm:

- Ice mask: Group threshold tests
- Ice concentration: tie-point algorithm
- GOES-R algorithm. Similar algorithm used for JPSS.
- AVHRR near visible and near infrared channel data, and surface temperature retrieved.

## Validation:

- Validation is done through comparison with PM ice concentration.



# Sea ice thickness/age – Energy budget method

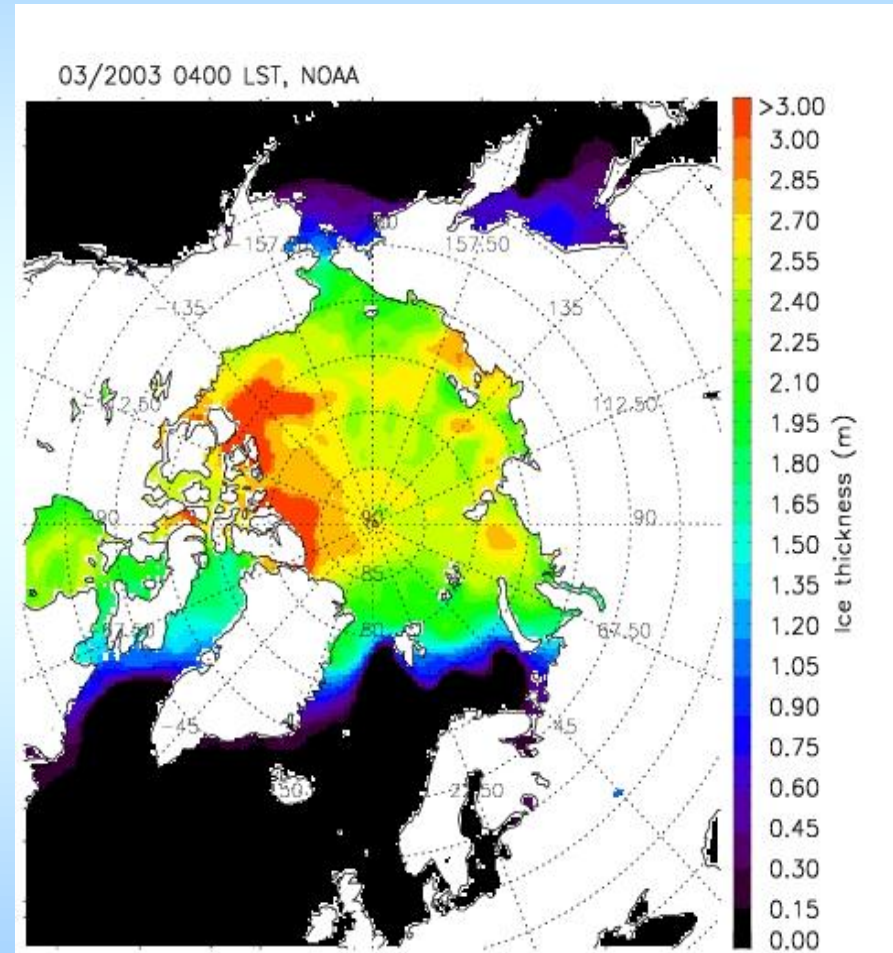
## Algorithm:

- One-dimensional Thermodynamic Ice Model (OTIM) based on the surface energy budget at the equilibrium state.
- Algorithm for GOES-R. Similar algorithm for JPSS.

## Validation:

- OTIM retrieved ice thickness with AVHRR, MODIS and SEVIRI were validated with in-situ observations, e.g., from submarine, mooring, and meteorological stations (Wang, Key, and Liu, 2010)

## Sea Ice Thickness





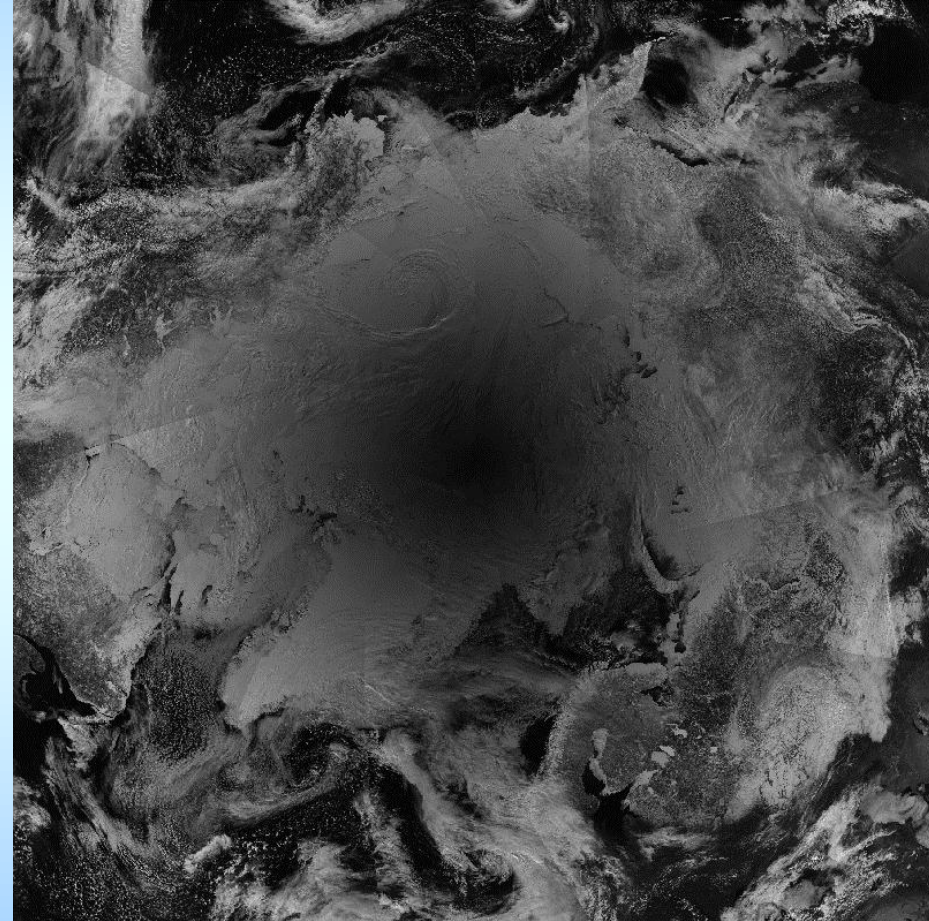
# AVHRR Polar Pathfinder 5 km EASE-Grid Composites

## Algorithm:

- Remap AVHRR level 1b data to 5 km EASE-Grid and make the composites at 0400 and 1400 local solar time (LST) in the Arctic, and 0200 and 1400 LST in the Antarctic.
- Five AVHRR channels, viewing angles, and Universal Coordinated Time (UTC) of acquisition.

*This product (APP) provides the brightness temperatures, reflectances, and viewing and illumination geometry needed for the generation of APP-x.*

Channel 1, Julian day 90, 2011



# APP-x Ice/snow surface temperature (IST)

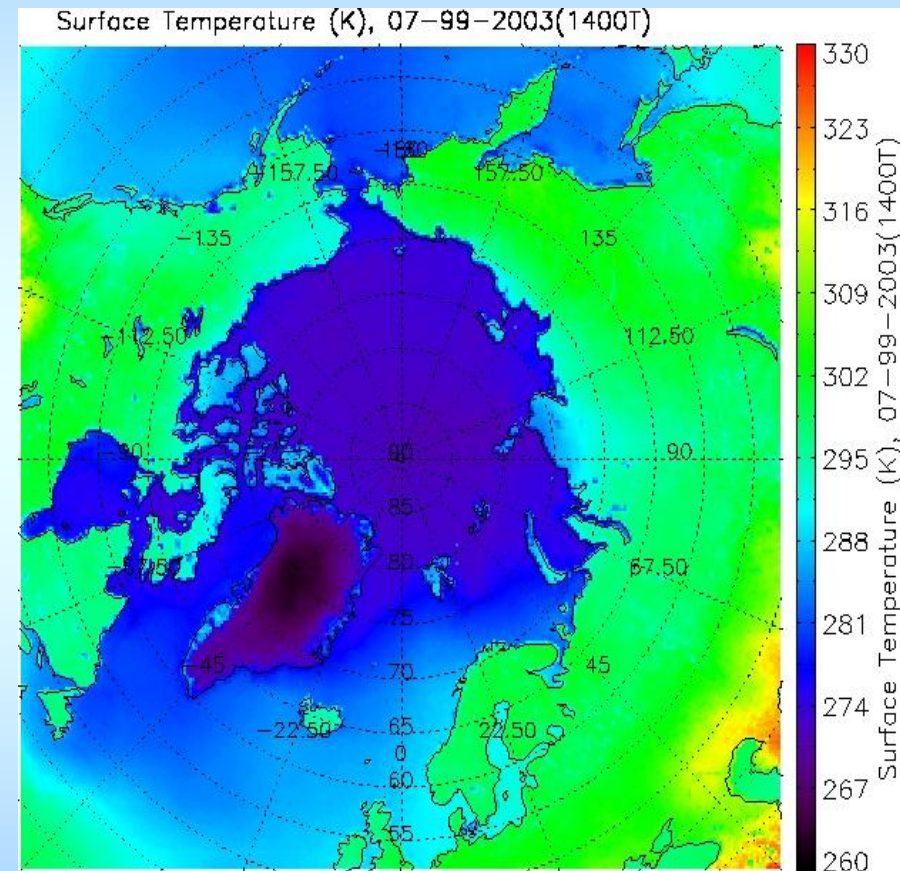
## Algorithm:

- Split window technique using AVHRR channel 4 and 5 with cloud adjustment for cloudy sky condition for snow and ice surface.
- Similar method used for JPSS.
- AVHRR channel 4 & 5 or equivalent sensors with near-infrared and atmospheric window channels.

## Validation:

- APP-x products were validated with in-situ observations (Xuanji Wang and Jeffrey R. Key, 2005, Arctic Surface, Cloud, and Radiation Properties Based on the AVHRR Polar Pathfinder Data Set. Part I: Spatial and Temporal Characteristics, J. Climate, Vol.18, No.14, 2558-2574, 2005.)

## Surface Skin Temperature



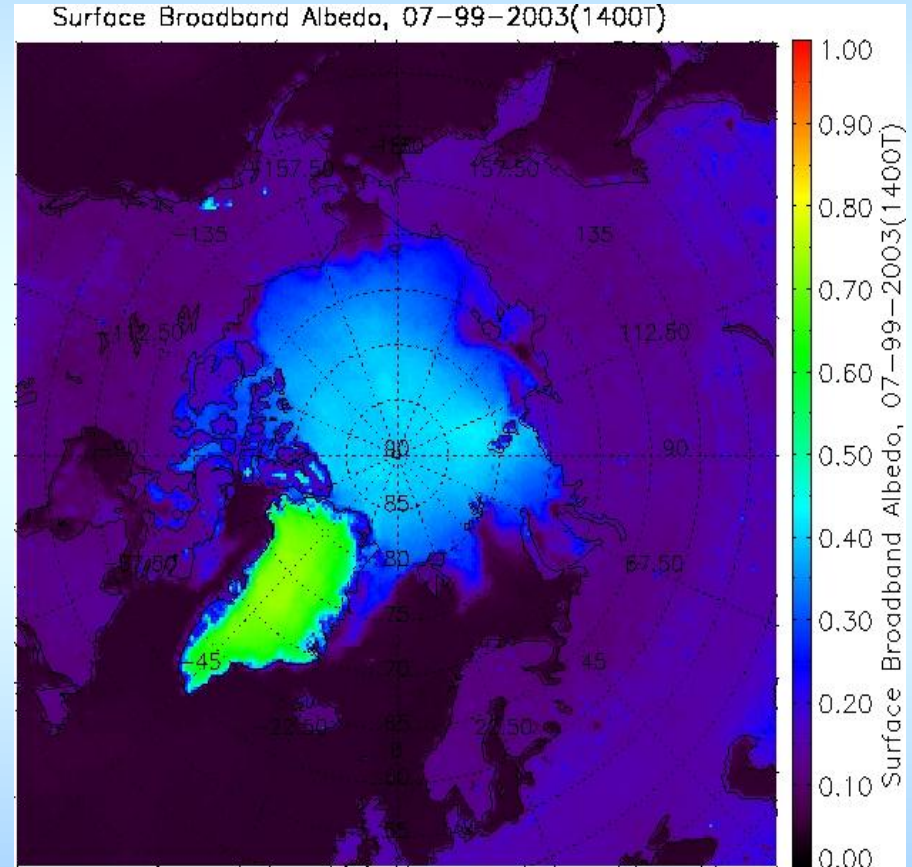


# APP-x Ice/snow surface broadband albedo

## Algorithm:

- Using AVHRR channel 1 and 2 with cloud adjustment for cloudy sky condition.
- AVHRR channel 1 & 2 or equivalent sensors with optical channels.

## Surface Broadband Albedo



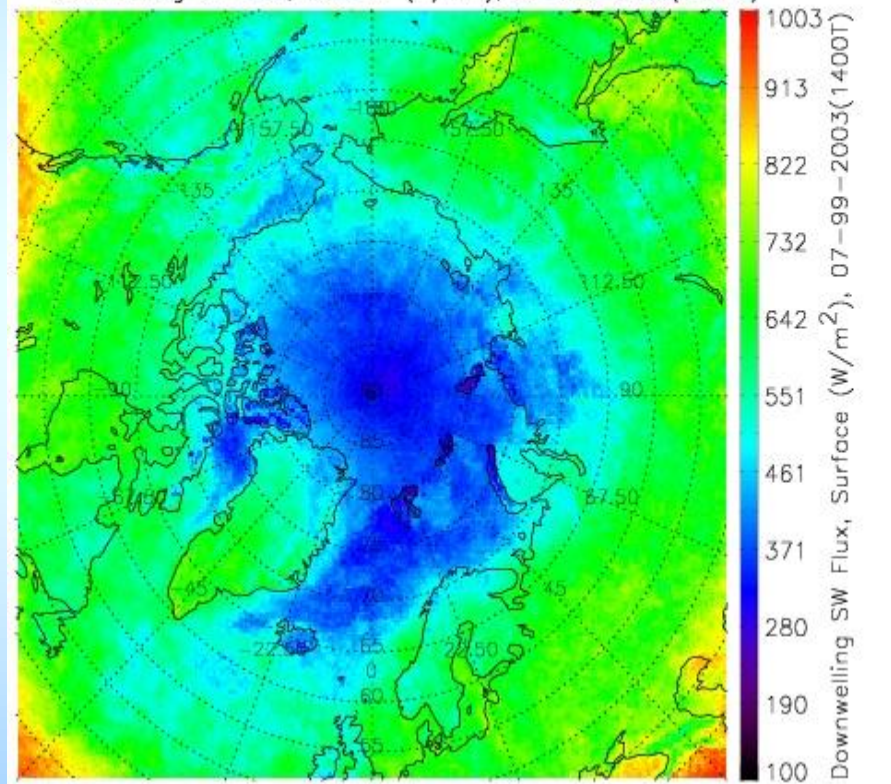
# APP-x surface shortwave and longwave radiation

## Algorithm:

- Forward radiative transfer calculation using a neural network version of radiation transfer model and derived products for clouds and surface properties.
- All AVHRR channels

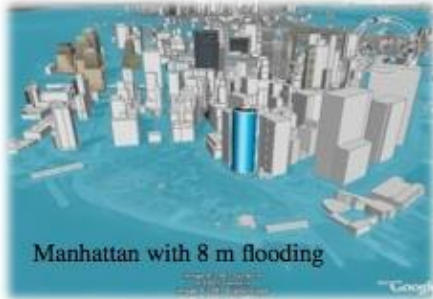
## Surface shortwave radiation flux, downward

Downwelling SW Flux, Surface ( $\text{W/m}^2$ ), 07-99-2003(1400T)



# A Changing Cryosphere is Important - *Globally*

Changes in the cryosphere can have significant impacts on water supply, transportation, infrastructure, hunting, fisheries, recreation, and ecology.



Sea level rise threatens vital infrastructure.

Changes in sea-ice affect access to the polar oceans and resources, tourism, and security. Declining summer sea-ice affects ocean circulation and weather patterns.



Natural hazards such as icebergs, avalanches and glacier outburst floods create risks.

Permafrost thawing impacts infrastructure and is potentially a major source of methane, a greenhouse gas.



Changes in the cryosphere impact water supply, transportation, food production, freshwater ecosystems, hydropower production.



Retreating sea ice results in a loss of habitat for mammals such as polar bears and seals.



# Applications

## ■ Climate models

- Comparison of concentration with CMIP5 model estimates
- Sea ice extent as baseline observation for ARCUS/SEARCH Sea Ice Outlook (<http://www.arcus.org/search/seaiceoutlook/>)
- Concentration provided to NCAR CESM for model verification

## ■ Biology/ecosystems

- Ice age to J. Davies, *Pew Environmental Group* (<http://www.pewenvironment.org>) and *Oceans North* (<http://www.oceansnorth.org>) to examine exploratory fisheries and potential ecosystem shifts in the high arctic
- The ice age product has been used to assess potential long-term survival of polar bears and for research aircraft flight planning (<http://content.usatoday.com/communities/sciencefair/post/2010/12/ice-refuge-may-be-polar-bears-last-stand/1>)
- Ice motion to R. Sambrotto, *Lamont-Doherty Earth Observatory*, to estimate biological productivity in the marginal ice zone



# Applications, cont.

## ■ National defense

- Regular communication with NORAD/NORTHCOM on state of Arctic sea ice in context of long-term strategic planning
- Ice age will be used in ONR-funded project on marginal ice zone
- Presentation to joint U.S.-Chile workshop on cryosphere remote sensing (24-27 July 2012)

## ■ Assessments

- Contribution to State of the Climate and State of the Arctic annual reports
- U.S. EPA Climate Indicators reports
- Ice concentration and age baseline sea ice data for AMAP SWIPA report
- PM sea ice data will be key part of IPCC AR5
- WMO Global Cryosphere Watch (in development)

# Applications, cont.

- **Commerce**
  - Contacts with oil companies
- **Science research example: coastal processes**
  - Sea ice loss and wave action along Alaskan coast (Overeem et al., GRL, 2011)
- **Policymakers**
  - Imagery and data provided to govt. agencies, NGOs, etc.
- **Education/Outreach**
  - Sea ice concentration/extent part of Earth Exploration Toolkit, <http://serc.carleton.edu/eet/seaice/>
  - Several workshops and seminars
- **Media/general public**
  - Annual Arctic sea ice minima press release
  - Greenland surface melt
  - Numerous contacts through the year



# Benefit to the Science Community

- User communities: Climate scientists, modelers (for verification), remote sensing scientists, Global Cryosphere Watch (GCW)
- Scientific discovery:
  - *The loss of the oldest, thickest Arctic sea ice continues at a record pace through mid-2011.* Viewed along with model estimates of low ice volume at the start of the melt season, it is likely that ice extent for September 2011 will continue the recent history of extreme seasonal minima. *The thinner ice cover is responding more dramatically to synoptic-scale variation both in the winter and summer (e.g., Maslanik, et al. Geophys. Res. Lett., July 2011).*
  - *Changes in sea ice concentration and cloud cover played major roles in the magnitude of recent Arctic surface temperature trends.* Significant surface warming associated with sea ice loss accounts for most of the observed warming trend. In winter, cloud cover trends explain most of the surface temperature cooling in the central Arctic Ocean.
  - *APP-x was used to study of controls on snow albedo feedback (SAF), which is important for assessing the validity of feedbacks in global climate models.*
  - An analysis of passive microwave sea ice concentration and MODIS cloud amount quantifies the effect of changes in sea ice extent and concentration on cloud amount. *A 1% decrease in sea ice concentration corresponded to 0.36~0.47 percent increase in cloud amount from July to November, suggesting a further decline in sea ice cover will result in a cloudier Arctic.*
  - Surface-temperature measurements of the Greenland Ice Sheet can be used to study temperature and melt trends.

# Schedule & Issues

- **State project status and plans for next phase of the project**
  - This is the end of the third, and last, project year.
  - There have been some variations on the products that were originally proposed, but all datasets have been, or will be in the very near future, generated.
  - With additional funding, these research projects can be transitioned to NCDC ops.
- **State any risks or concerns**
  - A no-cost extension was requested.
  - It is unclear exactly what is required to transition the products and documentation to NCDC. The requirements that have been discussed since last year are beyond the scope of what was originally proposed, e.g., ATBDs, providing source code, data formats.
  - Does NCDC want to/need to host all products? Some datasets are better left at elsewhere, e.g., passive microwave sea ice concentration at NSIDC; MODIS snow cover at GSFC. This needs to be discussed.
- **How can the CDR Program better assist you?**